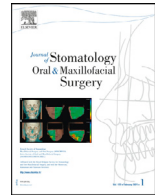




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Original Article

Volume assessment of the external contour around immediate implant with or without immediate tooth-like crown provisionalization: A digital intraoral scans study



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ABSTRACT

Purposes: To examine differences between immediate and delayed dental implant loading in maxillary aesthetic areas.

Methods: In this retrospective controlled analysis, 43 subjects who underwent immediate placement of the dental implant in a post-extraction socket were ranked into either immediate (24 implants loaded with non-occlusal tooth-like profile provisional prostheses fabricated by virtual diagnostic impressions and an in-office dental milling machine) or delayed group (19 implants loaded with conventional cover screws and secondary intention healing). Intraoperatively and then four months later, scans of the external layers were acquired with an optical scanner. The width of the alveolar crest and Jemt papilla index were acquired. Non-parametric tests were applied with a level of significance set at $p < 0.01$.

Results: In both groups, the volumes and areas showed significant reductions from the baseline to the 4-month survey. Reductions in volume appeared to be statistically different between the two groups ($-39 \pm 31 \text{ mm}^3$ for the immediate and $89 \pm 30 \text{ mm}^3$ for the delayed group). The final Jemt papilla index appeared significantly different between the immediate (mesial, 2.5 and, distal, 3) and delayed groups (2 for both aspects).

Conclusions: Immediate provisionalization significantly reduced volume loss and area shrinkage at the external layer when data were compared to a delayed rehabilitation strategy.

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1. Introduction

Several studies showed that a significant reduction in the volume of the alveolar process occurred between 6 months and 1 year after tooth extraction. They reported a 50% loss of the alveolar width at least with a smaller reduction in the alveolar height [1–3].

As a result of tooth loss, it was assumed that alveolar contours underwent reduction naturally but mainly at the buccal site. The amount of shrinkage depended on different features such as the size of the post-extraction socket, time and way of healing, and the site of the tooth to be extracted [4]. An interesting option was to delay implant placement in sockets preserved with bone grafting to save the dimension of the dental alveolus after tooth extraction as much

as possible. However, the filling materials did not allow for the complete preservation of the pristine areas of the alveolar ridge [5–8].

Moreover, simple surgical procedures for rehabilitation of edentulous areas were sometimes impossible cause they had even worsened by the presence of periodontal osseous defects such as dehiscence and fenestration.

These defects were often treated with the use of bone substitutes, such as synthetic, inorganic, and biologically organic combination instead of allogeneic ones, which were employed as void filler or proper augmentation materials [9,10]; other recipient sites required protection too by covering them with absorbable/non-resorbable membranes [11]. The results suggested that sites undergoing both concomitant treatments, that is, filling the bone materials in the gap created after immediate placement of dental implants and covering the grafted sites with membranes, showing the soft tissues to be healing well when compared to untreated sites (such as implant alone) [12].

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Immediate placement of a dental implant in a post-extraction socket followed by immediate restoration of a provisional crown was a trial-and-error approach in an attempt to improve prosthetic rehabilitations. Especially in the anterior areas where this protocol tended to be used more often for aesthetic purposes rather than functionality [13,14]. Some studies showed good effectiveness and predictability, particularly as they shared common features such as attainment of primary stability, absence of any occlusal contact, and integrity of post-extractive alveoli [14–16].

The present paper aimed to compare three-dimensional optical outcomes of the alveolar soft tissues after post-extraction socket implant placement in the esthetic zone with or without immediate provisionalization. The primary outcomes were volume and area modification. Secondary outcomes measured the changes in width and interproximal papillae.

2. Materials and methods

2.1. Study design/sample

Case sheets of subjects treated for rehabilitation with implant-supported crowns from 2019 to 2021 Tuscan Stomatologic Institute were gathered to acquire personal information of patients at the Maxillofacial Surgery of the University of Pisa. The study was conducted according to the guidelines of the Declaration of Helsinki of 2008 and updated in 2013 and was approved by the local Ethics Committee (Ethics Committee 2626–2008, PROT No. 58183 of the University of Pisa for retrospective studies). Each patient agreed to participate in the study by filling in written informed consent. The study was written based on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE). All relevant information was stored digitally in the analysis system.

Inclusion criteria:

- 18 years old or older.
- Signed an informed consent form for data analysis and processing.
- Single intercalate tooth extraction in the maxillary central and lateral incisor area.
- Presence of a dataset of two three-dimensional scans (file.stl or the virtual models) in the collected records, representing intraoperative views on just treated sites (acquired during tooth extraction) and on healed postsurgical areas (around 4 months later).
- Presence of uncorrupted computerized tomography scans (file.dcm) in the collected records after surgery; immediate or delayed provisionalization of post-extractive implants.

Exclusion criteria:

- History of systemic diseases contraindicating oral surgical intervention.
- Any report for bisphosphonate therapy.
- History of bone resection or radiation therapy (as part of an oncological treatment).
- Either corrupted file.dcm or file.stl.

Patients were intra- and postoperatively scanned with a 25 μ m precision 3-dimensional optical scanner (TRIOS 3, 3Shape A/S, Holmens Kanal, Copenhagen, Denmark), and post-surgical computerized tomography scans were saved in the records.

A matrix elaborator (MatLab 7.11, The MathWorks, Natick, MA, USA) read all information, such as stereolithographic and tomographic files which were voxelized [17]. Positions of all cloud data were triangulated to be superimposable to the tomographic occlusal plane [18]. The 16-bit three-dimensional clouds were superimposed on each other and on the tomographic file to detect the location of the implant direction and the level of the implant shoulder used as reference points for all the analyses.

Dicom images underwent volumetric, area, and linear measurements using dentascan software (SimPlant 12.02, Materialise Dental Italia, Roma, Italy) [19].

Volume Of Interest (VOI) was defined as the following. VOI domain was a parallelepiped with six faces: mesial and distal walls were tangential to the remaining teeth surfaces towards the treated site; buccal/palatal were perpendicular to the occlusal plane and included all three-dimensional data of the treated site; the apical boundary was set at 5 mm apical to the implant shoulder. A graphical section of the VOI was shown in Fig. 1.

A single-blind examiner and collector (T.P.) performed volume, area, and linear measurements.

2.2. Surgery and prosthetic procedures

All subjects had been treated with “one-shot” antibiotic administration (2 g amoxicillin or 0.6 g clindamycin for allergic patients). Each incisor was extracted with an atraumatic magneto-electrical technique (Magnetic Mallet, www.osseotouch.com, Turbigo, Milano, Italy) [13]. After tooth extraction, no augmentation of the external alveolar contour was performed. Each implantation site was prepared with a standard drill at least 4 mm beyond the root apex, following the palatal bony walls as a guide. Titanium (Ti) implants were Ti plasma-sprayed with a rough surface, and progressive thread design (Prima®; Sweden & Martina, Padova, Italy); Implant stability was assumed by Osstell measurement (Osstell system; Osstell AB, Gothenburg, Sweden). If a gap between the fixture and the buccal wall of the post-extraction socket was present, it was filled with a small cut

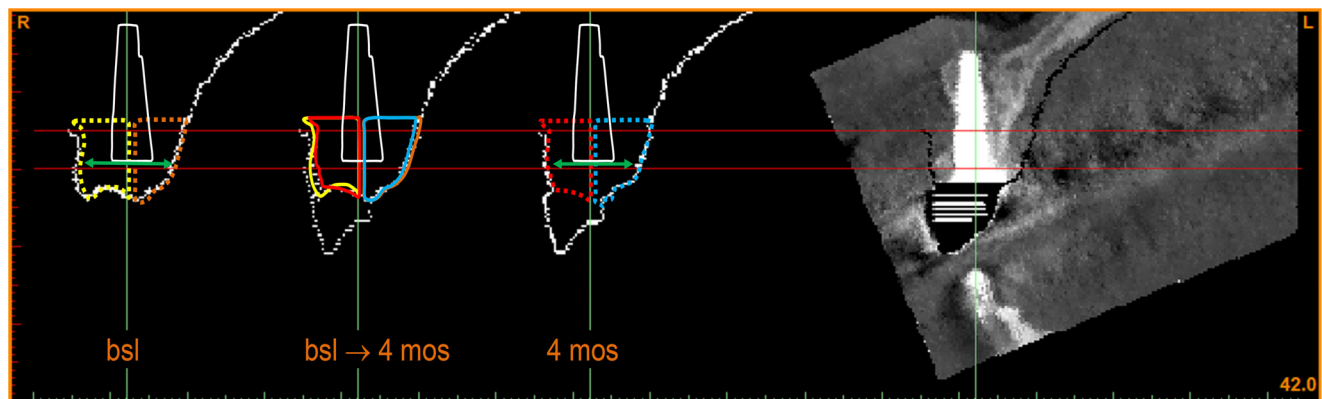


Fig. 1. Buccal (on the right) and palatal (on the left) volume measurements in (ABC) cross sectional views of 3D .stl clouds at baseline (A), at 4 months (C), and their superimposition (B) within the VOI. Crestal width at level of the implant shoulder in green solid line at baseline and at 4 months. Implant edges in white solid line; (D) superimposition view of computerized tomography scans with voxelized digital intraoral scans.

piece of sterile absorbable gelatin sponge (Cutanplast® Dental, Dispo-tech S.r.l., Gordona, SO, Italy) to permit hemostasis.

In the immediate provisionalization group (*imm*), provisional prostheses with a tooth-like profile were obtained with a virtual diagnostic impression and an in-office dental milling machine (K5+ VHF camfacture AG, Ammerbuch, Germany) mimicked the shape of a pristine tooth emergence profile. The core of the provisional crown was fabricated through a subtractive milling technique in polymethyl methacrylate (PMMA) material in discs (Dentsply Sirona, Multilayer PMMA Disc, Smile Way, York, U.S.A.) and the dental implant was immediately loaded to support soft tissue and maintain the socket dimension as immediate prosthesis but with no occlusal loading (Fig. 2).

In the delayed group (*del*), a conventional cover screw had been screwed on each dental implant; the site was covered with a collagen sheet (Condress; Smith & Nephew, Agrate Brianza, Italy) and then left to heal by secondary intention for two/three months allowing to perfectly integrating.

In the fourth month, the final crowns were delivered.

2.3. Outcomes

Descriptive variables were the following: age, gender, and smoking habits.

2.3.1. Primary predictors

Immediate group (*imm*) with an immediate provisionalization versus delayed group (*del*) with a delayed prosthetic strategy;

2.3.2. Secondary predictors

Basal versus palatal aspect.

The investigator measured anatomical variables, such as volumes and areas of the stereolithographic contours within the VOI at the intraoperative time point or baseline (bsl) and 4 months after tooth extraction (4mos). The buccal and palatal aspects had been investigated separately by using the dental implant as a reference structure (Fig. 1). All anatomical measurements were positive.

V: volume of the contour of the virtual digital model within the standardized VOI, respectively, at bsl and 4mos.

A: area of the contour of the virtual digital model within the standardized VOI at bsl and 4mos.

W: width of the alveolar crest at the level of implant shoulder. The three-dimensional overlap allowed the clinician to detect the implant shoulder also in the preoperative scans (Fig. 1)

JPI: Papilla Index (PI) of Jemt consisted in ranking each papilla compared to the line through the zenith of the implant restoration to that of the adjacent tooth [20].

The resonance frequency analysis (RFA) was measured and expressed in the implant stability quotient (ISQ) [21].

2.3.3. Secondary outcome variables

All outcomes were obtained by a series of algebraic manipulations of the primary ones. The secondary outcomes were usually negative and represented a loss in volume or a reduction in surface and distance.

Volume change of the alveolar ridge from baseline to 4 months, or ΔV and its analogous in terms of percentage were respectively given by Equations (1) and (2):

$$\Delta V = V_{4mos} - V_{bsl}$$

$$\Delta V\% = 100 \times (V_{4mos} - V_{bsl}) / V_{bsl}$$

Change at the surface with its loss in terms of percentage were given by Equations (3) and (4)

$$\Delta A = A_{4mos} - A_{bsl}$$

$$\Delta A\% = 100 \times (A_{4mos} - A_{bsl}) / A_{bsl}$$

Change in the width of the alveolar ridge was given by Equations (5)

$$\Delta W = W_{4mos} - W_{bsl}$$

2.4. Statistical analysis

All statistics were carried out in the Matrix Laboratory software (Statistics Toolbox, MatLab 7.11; The MathWorks, Natick, MA, USA). The null hypothesis (H_0) was that: there is no difference between the immediate provisionalization group and the delayed prosthetic loading protocol. Homoscedasticity was tested by the Brown-Forsythe test and Gaussian distribution was tested by the Shapiro-Wilk analysis. Measurements repeated in time were paired data; each pair-wise comparison was performed by Wilcoxon signed-rank test. Unmatched samples were compared by the Wilcoxon rank-sum test. Variables are described as mean $\pm$ standard deviation or median (interquartile range). The level of significance was set at 0.01.

3. Results

An accurate demographic description was shown in Table 1.

Very few episodes of minor inflammation were recorded during the first days after implant placement.

Both in the immediate and delayed groups the volumes (from $849 \pm 187 \text{ mm}^3$ to $809 \pm 186 \text{ mm}^3$ and from $850 \pm 154 \text{ mm}^3$ to $761 \pm 151 \text{ mm}^3$, for *imm* and *del* groups, respectively) and areas (from $643 \pm 116 \text{ mm}^2$ to $610 \pm 121 \text{ mm}^2$ and from $629 \pm 80 \text{ mm}^2$ to $582 \pm 72 \text{ mm}^2$, for *imm* and *del* group, respectively) showed significant reduction (with $p\text{-values} \leq 0.0003$) from baseline to the 3-month survey. However, just reductions in volume ($-39 \pm 31 \text{ mm}^3$ for *imm* group and $89 \pm 30 \text{ mm}^3$ for the *del* group) appeared to be statistically different between the two groups with a $p\text{-value} < 0.0001$ (Fig. 3).

Data regarding the crestal widths and their changes in time were shown in Table 2. Both in the immediate and delayed groups the crestal widths did not show significant modifications ($+0.25 \pm 0.74 \text{ mm}$ for *imm* group and $-0.49 \pm 0.79 \text{ mm}$ for *del* group), however, results at 4 months for the immediate group seemed to be much better than that of the delayed group ($p\text{-value}=0.0017$).



Fig. 2. immediate loading: (A) preoperative site; (B) implant placement; healed site after provisionalization with (C) and (D) without provisional crown; clinical aspect of peri-implant soft tissues 4 months later with final prosthesis (E).

Table 1
Descriptive (mean, standard and deviation) with statistical analyses. Volumes and areas at baseline (bsl) and 4 months (4mos). Statistics: Wilcoxon signed-rank test^o, Wilcoxon rank-sum test^{*}, and Homoscedasticity assumption and results of Brown-Forsythe's test; p with significance at 0.01 level (2 tailed) in bold.

		immediate provisionalization (<i>imm</i>)						delayed prosthesis (<i>del</i>)						imm vs. del			
Gender (F/M)		19/5						15/4									
Smokers (Y/N)		3/21						3/16									
Age (year)		42.3 ± 5.7						43.2 ± 5.2									
time		N	bsl	4mos	bsl → 4mos	Δ%	bsl vs. 4mos	N	bsl	4mos	bsl → 4mos	Δ%	bsl vs. 4mos	bsl	4mos	bsl → 4mos	Δ%
Wilcoxon							°						°	*	*	*	*
volume (<i>mm</i> ³)	<i>buccal</i>	24	406 ± 105	362 ± 104	−43 ± 37	−10.8 ± 8.0	0.0001	19	448 ± 88	375 ± 86	−72 ± 31	−16.5 ± 6.9	0.0001	0.1786	0.5169	0.0074	0.0080
Shapiro-Wilk	<i>p-value</i>		0.4395	0.0926	0.1981	0.2309			0.6984	0.6640	0.8519	0.5114					
Brown Forsythe	<i>variance</i>		11,033	10,935	1414	64.4			7874	7459	983	48.0					
volume (<i>mm</i> ³)	<i>palatal</i>	24	442 ± 90	446 ± 94	+3 ± 24	+0.7 ± 5.0	1	19	401 ± 77	385 ± 76	−16 ± 5	−4.2 ± 1.4	0.0001	0.1175	0.0399	<0.0001	<0.0001
Shapiro-Wilk	<i>p-value</i>		0.2278	0.1922	<0.0001	<0.0001			0.0817	0.0625	0.9021	0.4363					
Brown Forsythe	<i>variance</i>		8205	8920	585	25.8			5982	5902	30	2.0					
buccal versus palatal	<i>p-value</i>		0.0045	<0.0001	0.0001	0.0001			0.0035	0.6873	0.0002	0.0002					
homoscedasticity assumption and results of Brown-Forsythe's test for the variables																	
<i>F</i> = 0.8113, <i>df</i> ₁ = 7, <i>df</i> ₂ = 164, <i>p</i> = 0.5790																	
volume (bsl & 4mos)																	
volume (bsl → 4mos)																	
volume (Δ%)																	
area (<i>mm</i> ²)	<i>buccal</i>	24	368 ± 78	341 ± 82	−26 ± 19	−7.5 ± 4.8	<0.0001	19	373 ± 54	323 ± 50	−49 ± 16	−13.2 ± 3.8	0.0001	0.4706	0.6161	0.0003	0.0002
Shapiro-Wilk	<i>p-value</i>		0.1225	0.0519	0.1322	0.0626			0.8137	0.3389	0.9564	0.2322					
Brown Forsythe	<i>variance</i>		6117	6775	368	23.3			3003	2556	276	14.5					
area (<i>mm</i> ²)	<i>palatal</i>	24	405 ± 61	403 ± 65	−1 ± 19	−0.5 ± 4.6	0.0761	19	373 ± 43	354 ± 40	−19 ± 8	−5.0 ± 2.1	0.0001	0.1420	0.0165	0.0001	<0.0001
Shapiro-Wilk	<i>p-value</i>		0.0282	0.0092	<0.0001	<0.0001			0.6796	0.6211	0.3639	0.6088					
Brown Forsythe	<i>variance</i>		3797	4335	385	21.5			1855	1631	75	4.4					
buccal versus palatal	<i>p-value</i>		0.0015	0.0002	0.0005	0.0001			0.8562	0.0006	0.0002	0.0003					
homoscedasticity assumption and results of Brown-Forsythe's test for the variables																	
volume (bsl & 4mos)																	
volume (bsl 4mos)																	
volume (Δ%)																	
<i>F</i> = 1.4317, <i>df</i> ₁ = 7, <i>df</i> ₂ = 164, <i>p</i> = 0.1958																	
<i>F</i> = 1.5415, <i>df</i> ₁ = 3, <i>df</i> ₂ = 82, <i>p</i> = 0.2100																	
<i>F</i> = 1.5741, <i>df</i> ₁ = 3, <i>df</i> ₂ = 82, <i>p</i> = 0.2019																	

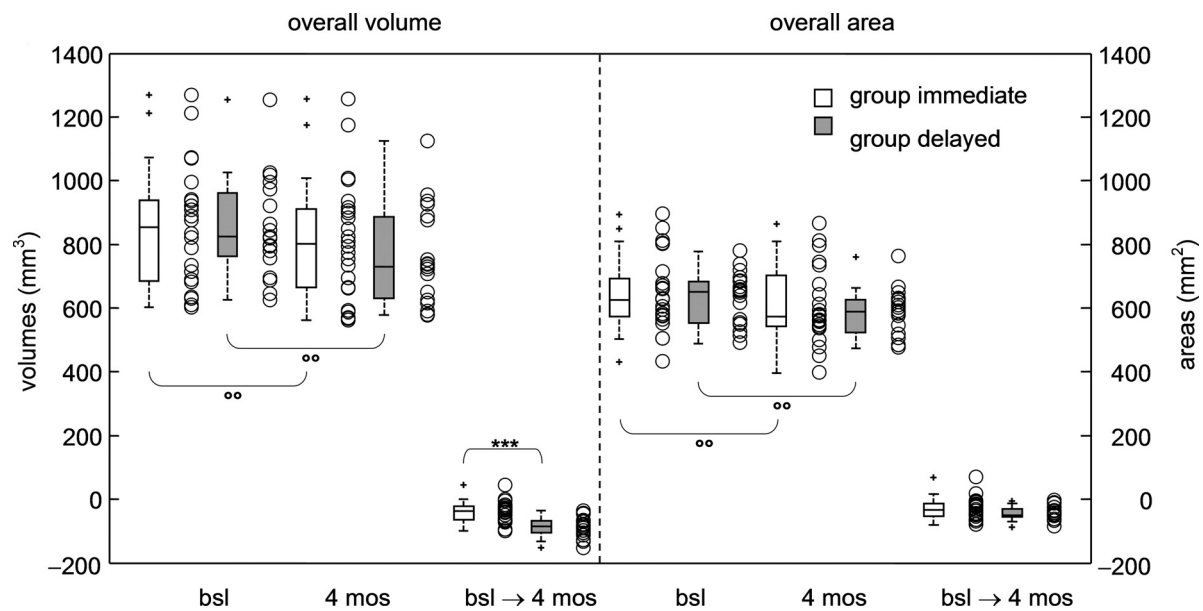


Fig. 3. Scatter (empty points) and box plots for volumes and areas at baseline (bsl), 4 months (4mos) and from baseline to 4 months ((bsl → 4mos). In box-and-whiskers plot outliers (solid X) were data with values beyond the ends of the whiskers. Wilcoxon signed rank test ° and Wilcoxon rank sum test *: °/* significant (p -value < 0.01), °°/°°° extremely significant (p -value < 0.0001).

The final Jemt papilla index appeared significantly different (with p -values ≤ 0.005) between *imm* (2.5 and 3, respectively for the mesial and distal site) and *del* group (2 for both the mesial and distal aspects); however, a significant decrease from baseline to 4 months was registered also in the immediate group even if only for the mesial aspect (from 3.0 to 2.5).

When volume and area variables were analyzed and compared to each other according to the secondary predictor, buccal sites showed outcomes that seemed to be worse than the palatal ones (Table 1). The loss in volume and area seemed to be localized exclusively on the buccal side (with -10.8 ± 8.0 mm³ and -7.5 ± 4.8 mm² in the immediate group and with -16.5 ± 6.9 mm³ and -13.2 ± 3.8 mm² in the delayed group).

4. Discussion

This study was intended to detect if immediate provisionalization should give better results in terms of volume and dimensional preservation of the alveolar crestal site treated with immediate implant placement in extraction sockets; immediate implants and conventional abutments with delayed prosthesis protocol served as the study control group.

There were many features that positively or negatively could affect the volume remodeling of the post-extraction site such as the use of gap filling with connective tissues [22] or augmentation techniques employing bone graft substitutes when defects appeared too great to ensure proper dental implant support [23,24]. In this view, also the prosthetic timing and type of the healing caps could affect the healing process and clinical outcomes; [25] for example, a tooth-form like immediate provisionalization might cause the mucosa around and supporting dental implant to have a form equivalent to soft tissues surrounding the pristine tooth [26]. And even if through crown contour modification the clinician could control the marginal level of peri-implant soft tissue, this prosthetic step was time-consuming, costly, and complex [27,28]. On the contrary, an immediate provisionalization at once allowed the patient to reduce the dimensional change of the soft tissue post-tooth extraction and implant placement and promptly work as a mechanical barrier against the oral environment even more so for infected areas [29]. The present technique suggested mimicking the shape of the pristine tooth

(before extraction); the milled immediately fixed crown provided physical support towards the peri-implant tissues, reduced major and minor progressive mechanical trauma, and gave permanent biological stability to the epithelial attachment [30].

The present paper reported volume changes, area, and linear reduction in the alveolar crest contour of patients who underwent implant placement in post-extraction sites of a single tooth in the maxillary esthetic zone with or without immediate provisionalization. They suggested that, at 4 months survey, the loss in volume of the immediate group was about half of the delayed group (-4.8% versus -10.7%). When the areas of the buccal and palatal aspects of the incisors were separately measured, the major problem that the clinician had to face in terms of area shrinkage was represented by the buccal area. While area reduction within the volume of interest was negligible in patients treated with an immediate provisionalization protocol in the palatal aspect (-0.5%), again, the loss in the buccal area of the immediate group was about half of the delayed group (-7.5% versus -13.2%). These data were in line with another report which registered a 1-year change in volume of 17.4% at the buccal aspect [31]. Moreover, a recent meta-analysis, describing peri-implant soft tissue changes in aesthetic areas after immediate implant placement and provisionalization, suggested that a volume loss could not yet be completely prevented either with or without sub-epithelial connective tissue graft treatments [32].

Immediate non-occlusal loading with a tooth-like provisional prosthesis was just one step out of several others which the clinician had planned to reduce the loss in the dimension of the post-extractive alveolus during tooth replacement therapy. The first two steps were directed to a minimally invasive extraction and an atraumatic surgery as much as possible, that is, the use of a magnetoelectric mallet as a subluxation device that preserved the integrity of the alveolus and did not create post-extraction bony defects; on the other hand, the dental implant might be immediately placed without touching the surrounding soft tissues or reflecting a flap.

As described in a very recent study, atraumatic tooth avulsion could significantly counteract the post-extraction alveolar volume loss (22.3%, which was half the size of the traumatic extraction one at least in the posterior site) [17]. But it was with all the above-mentioned surgical and prosthetic strategies that clinicians could achieve

Table 2
Descriptive with mean $\pm$ standard deviation or median (interquartile range) with statistical analyses. Crestal width and Jemt Papilla Index at baseline (bsl) and 4 months (4mos). Statistics: Wilcoxon signed-rank test*, Wilcoxon rank-sum test*, and Homoscedasticity assumption and results of Brown-Forsythe's test; p with significance at 0.01 level (2 tailed) in bold.

time	immediate provisionalization (imm)				delayed provisionalization (del)				imm vs. del			
	N°	bsl	4mos	bsl $\rightarrow$ 4mos	$\Delta\%$	N°	bsl	4mos	bsl $\rightarrow$ 4mos	$\Delta\%$	bsl	4mos
Wilcoxon												
width (mm)	24	12.46 $\pm$ 0.68	12.71 $\pm$ 1.14	+0.25 $\pm$ 0.74	+1.91 $\pm$ 6.11	19	12.08 $\pm$ 0.83	11.58 $\pm$ 1.03	-0.49 $\pm$ 0.79	-4.04 $\pm$ 6.19	0.0782	0.0007
Shapiro-Wilk		0.4526	0.0673	0.0735	0.0311		0.5034	0.0971	0.0357	0.0660	0.0017	0.0013
Brown Forsythe		0.46	1.30	0.54	37.3		0.68	1.06	0.61	38.3	*	*
width (bsl & 4mos)												
width (bsl $\rightarrow$ 4mos)												
width ($\Delta\%$)												
JPI	24	3.0 (1.0)	2.5 (1.0)								0.5603	0.0003
JPI	24	3.0 (1.0)	3.0 (1.0)								0.9062	0.0050

at buccal site minimum alveolar volume loss (−10.8%) and area shrinkage (−7.5%).

In the present study, immediate provisionalization showed to maintain aesthetic outcomes such as the papilla index very high with only a slight reduction in the mesial aspect from baseline (3) to the 4-month survey (2.5). On the other hand, in the delayed group a median final index of 2 had been registered both for the mesial and distal sites. These findings seemed to agree with a recent paper which concluded that patients receiving immediate CAD/CAM customized healing abutments obtained higher functional implant prosthodontics scores than the group treated with standard healing abutments [33].

The following limitation could be defined as described below. First of all, the retrospective nature of the study on patients just treated in a single rehabilitation center; but in the framework of the present analysis, it was necessary to collect homogeneous and consistent data about intraoral three-dimensional scans. This affected the size of the sample which appeared to be restricted due to the need of superimposing each layer to the respective postoperative tomography scans. Moreover, each of the selected patients might have a complete set of digital intraoral scans that should be readable and not corrupted. The highly inter-individual variability in root and crown shape of the teeth belonging to a random group of patients made the analysis of the data more difficult also for the fact that not easily defined errors might be caused by the overlapping process of the images and contours. Even if the device for three-dimensional acquisition of the digital cast had a high scanning definition experimental errors could be generated primarily by the presence of oral fluids such as blood, saliva, and gingival crevicular fluid.

No extrapolation could be performed with the results of volume loss of the underlying bone, so, a prospective split-mouth study should shed more light on the outstanding issues and clarify in a much better way the effect of immediate and delayed temporization on peri-implant tissue.

The analysis of the 4-month survey suggested that immediate provisionalization had reduced volume loss and area shrinkage at the external layer when data were compared to a delayed rehabilitation strategy. Moreover, in the buccal aspect, the loss in volume and area of the immediate group was about half of the delayed group.

Declaration of Competing Interest

The authors declare no conflict of interest.

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